

Reciprocal Association Between Atopy and Respiratory Symptoms in Fully Employed Female, but Not Male, Workers in Swine Operations

James A. Dosman, MD
Liliane Chenard, PEng, MSc
Donna C. Rennie, PhD
Ambikaipakan Senthilselvan, PhD

ABSTRACT. In large commercial swine operations, workers are exposed to indoor air-contaminants during their work-shift. In recently developed large swine operations, exposures are typically 8 or 12 hours/day and females account for a sizeable proportion of the workers. Implications of enhanced exposures and gender require evaluation. Two hundred and forty male and 134 female swine barn workers and 184 male and 227 female nonfarming rural dwellers (controls) (mean age $\pm$ SD males: 36.2 ± 11.9 ; females: 34.9 ± 10.7) completed respiratory questionnaires. Of these, 348 workers (93.0%) and 401 controls (97.6%) underwent allergy skin prick tests (house dust mite, *Alternaria* sp., hog, cat, mixed grass). The number of hours worked per day was 8.2 for female workers and 7.7 for male workers. Atopy was present in 38.7% and 29.4% of male and female workers, and 46.9% and 38.3% of male and female controls. There was a 72% reduction in risk for chronic phlegm and 70% reduction in usual phlegm in female workers with atopy in comparison to female controls without atopy. There was a significantly increased risk for chronic and usual phlegm, and chronic and usual cough in male workers with atopy. Female workers with atopy were at increased risk for asthma. These findings, that atopy in exposed female workers may be protective of symptoms suggestive of chronic bronchitis but that atopic female workers may be more susceptible to the development of asthma, suggest that exposures to inhaled substances in the workplace may be mediated differently in male and female workers.

KEYWORDS. Asthma, atopy, females, males, respiratory, swine exposures, symptoms

INTRODUCTION

Swine production in Saskatchewan and elsewhere has been changing in the last decade, with small swine operations managed primarily by

individual mainly male farmers with 2 to 3 hours per day exposure being replaced by large swine operations with full-time employees working 8 to 12 hour work shifts.¹ This change has resulted in an increased number of hours of exposure per

James A. Dosman, Liliane Chenard, and Donna C. Rennie are with the Canadian Centre for Health and Safety in Agriculture, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.

Ambikaipakan Senthilselvan is affiliated with the Department of Public Health Sciences, School of Public Health, University of Alberta, Edmonton, Alberta, Canada.

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Address correspondence to: Ambikaipakan Senthilselvan, PhD, Department of Public Health Sciences, School of Public Health, University of Alberta, Edmonton, AB, T6G 2G3 Canada (E-mail: sentil@ualberta.ca).

day, and the emergence of a workforce comprised of both male and female swine workers.¹

Workers in swine barns are exposed to airborne contaminants that include dust particles, endotoxin, ammonia, and hydrogen sulphide.²⁻⁶ Previous studies conducted primarily on part-time male swine farmers have shown adverse respiratory effects including increases in respiratory symptoms,⁷ reduction in pulmonary function tests,⁷ increases in bronchial responsiveness,⁸ and excessive longitudinal declines in lung function.⁹⁻¹¹ Recently, we reported on an increased risk of respiratory symptoms in fully employed male and female workers in large modern swine operations.¹ As there has been previous evidence that lung function in women may be affected differently by environmental exposures than in men,¹²⁻¹⁵ we undertook to determine whether sex might be an effect modifier in the association between atopic status and respiratory outcomes in exposed swine workers.

METHODS AND MATERIALS

Selection of Swine Workers

All swine workers were employees of commercial swine producing operations ranging in size from 20 to 200 employees. Those workers aged 17 years or older and working in the confinement building for at least 4 days per week, with a total work duration of 20 hours or more per week, were invited to participate in the study. In total, 348 (93.0%) swine workers (222 men and 126 women) and 401 (97.6%) nonfarming controls (179 men and 222 women) had skin-prick testing and were considered for this study.

Selection of Nonfarming Controls

Nonfarming control subjects were chosen from the taxation lists of villages or towns within an approximately 100 km radius of a swine production site. All control subjects lived in the villages or towns, and there were no immediate environmental exposures to swine barns. Nonfarming rural dwellers who were involved in occupations such as mining, grain

handling, metal, and auto-body work were excluded. Age limits for controls were the same as for the swine workers. In total, 411 nonfarming rural dwellers were considered for the initial study.

Skin-Prick Testing

Skin-prick tests for house dust mite, *Alternaria* sp., swine, cat, and mixed grass allergens and positive (histamine) and negative (saline) controls were conducted. Subjects were considered atopic if they had a raised wheal to any of the above allergens that was >3 mm of the saline control.

Questionnaire

The following questions were used to define respiratory symptoms and asthma: usual phlegm (Do you usually bring up phlegm from your chest [count phlegm with first smoke or first going outside?]); chronic phlegm (Do you usually bring up phlegm like this as much as twice a day, 4 or more days out of the week? [This question followed the question on usual phlegm]); usual cough (Do you usually cough as much as 4 to 6 times a day, 4 or more days out of the week?); chronic cough (Do you usually cough like this on most days for 3 consecutive months or more during the year?); and asthma (Has a doctor ever told you that you have asthma?).

Smoking status was divided into current smokers, ex-smokers (persons who had smoked more than 400 cigarettes [or equivalent amount of tobacco] in his/her lifetime but were not currently smoking), and nonsmokers.

Activities at Work

The work-related activities and time spent in these activities were obtained in different swine production stages: farrowing, nursery, grower/finisher, breeding/gestation, and "other" activities. A worker may engage in more than one of these activities on a single working day.

Statistical Methods

Descriptive statistics including frequencies and percentages and means and standard deviations

were used to describe categorical and continuous variables. Differences in the means were examined by two independent samples, *t* tests, or Mann-Whitney *U* tests. Chi-square tests were used to test the differences in proportion of symptoms and asthma between workers with and without atopy. To determine whether sex modified the relationship between atopy and symptoms and asthma, multivariate logistic regression analysis was used with age, years worked in the swine industry and smoking as potential confounders.

RESULTS

As shown in Table 1, mean ages, heights, and weights of male swine workers were not significantly different compared to male control participants, and mean ages, heights, and weights of female swine workers were not significantly different compared to female control participants, although there were significant height and weight differences between the sexes in each group. Hours per day worked were greater among female workers than

among male workers, but days per week worked and years worked were greater in males than in females. There were no significant differences in the proportions of current or past smoking status between the worker groups and the control groups, or between male and female workers.

A greater proportion of females (54.8%) than males (36.5%) worked in farrowing ($p < .001$, chi-square tests with one degree of freedom between male and female workers) and within farrowing, the females worked more hours per day (6.7 ± 2.7 versus 2.9 ± 2.7 ; $p < .001$, Mann-Whitney *U* test). However, greater proportions of males compared to females worked in grower/finishing (57.2% versus 26.2%; $p < .001$) and in breeding/gestation (46.0% versus 26.2%; $p < .001$) (data not shown). As well, the prevalence of atopy as defined by a positive skin test to house dust mite was more common in male workers than in female workers (21.6% versus 12.7%; $p < .05$, chi-square tests with one degree of freedom between male and female workers) and in male controls than in female controls (22.9% versus 14.0%). There was no difference

TABLE 1. Characteristics of Swine Workers and Nonfarming Controls by Sex

Variable	Swine workers		Nonfarming controls	
	Males (<i>n</i> = 222) Mean $\pm$ SD	Females (<i>n</i> = 126) Mean $\pm$ SD	Males (<i>n</i> = 179) Mean $\pm$ SD	Females (<i>n</i> = 222) Mean $\pm$ SD
Age, year	36.4 $\pm$ 11.9*	34.7 $\pm$ 10.8†	39.7 $\pm$ 12.5*	38.9 $\pm$ 12.5†
Height, cm	177.0 $\pm$ 6.1	164.4 $\pm$ 5.6	178.3 $\pm$ 6.8	164.6 $\pm$ 6.6
Weight, kg	88.1 $\pm$ 16.6	75.6 $\pm$ 15.2	90.2 $\pm$ 17.9	75.6 $\pm$ 17.0
Hours per day ^{II}	7.7 $\pm$ 1.7	8.2 $\pm$ 1.0*	—	—
Days per week ^{II}	5.6 $\pm$ 1.0	4.9 $\pm$ 0.4††	—	—
Hours per week ^{II}	42.6 $\pm$ 11.0	40.3 $\pm$ 5.2	—	—
Years worked ^{SS}	6.5 $\pm$ 7.0	4.1 $\pm$ 4.1††	—	—
Smoking	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)
Nonsmoker	90 (40.5)	55 (43.7)	93 (52.0)	127 (57.2)
Current smoker	64 (28.8)	41 (32.5)	36 (20.1)	37 (16.7)
Ex-smoker	68 (30.6)	30 (23.8)	50 (22.9)	58 (26.1)

* $p = .01$

† $p = .002$ from two-independent sample *t* tests for comparison between swine workers and nonfarming controls.

** $p = .005$

†† $p < .001$

‡‡ $p = .003$ from Mann-Whitney *U* tests for comparison between males and females.

^{II}Hours per day, days per week, and hours per week worked at the current swine operation.

^{SS}Years worked in any swine operation.

in prevalence of atopy between workers and controls for either male or female workers (data not shown).

Figure 1 shows the prevalence of chronic and usual phlegm for nonatopic and atopic males and females among swine workers and controls. There was a significantly increased prevalence of chronic phlegm production in atopic male workers compared to nonatopic male workers, but there was a significantly decreased prevalence of chronic phlegm production among atopic female workers compared to nonatopic female workers. Among nonfarming controls, the prevalence of chronic phlegm production was low in both males and females, and there were no differences between nonatopic and atopic individuals. As well, a similar pattern was present for usual phlegm. However, as demonstrated in Figure 1, the prevalence of doctor-diagnosed asthma was greater among atopic than nonatopic female workers, but this

difference was not seen among male workers (Figure 1). Considering chronic and usual cough and atopy, atopic male workers had significantly higher prevalence of chronic and usual cough than did nonatopic male workers, but atopic female workers had significantly lower prevalence of chronic cough than did nonatopic female workers (data not shown).

In swine workers, after controlling for age, years worked, and smoking, a significant interaction between atopy and sex was observed in the logistic regression model for chronic phlegm ($p = .007$), usual phlegm ($p = .03$), chronic cough ($p = .006$), and usual cough ($p = .04$), whereas no significant interaction between atopy and sex was observed for asthma. None of these interactions were significant in non-farming controls.

As demonstrated in Table 2, a multiple logistic regression analysis controlling for age, years worked, and smoking continued to show that

FIGURE 1. Prevalence of chronic and usual phlegm, and asthma by atopy and sex.

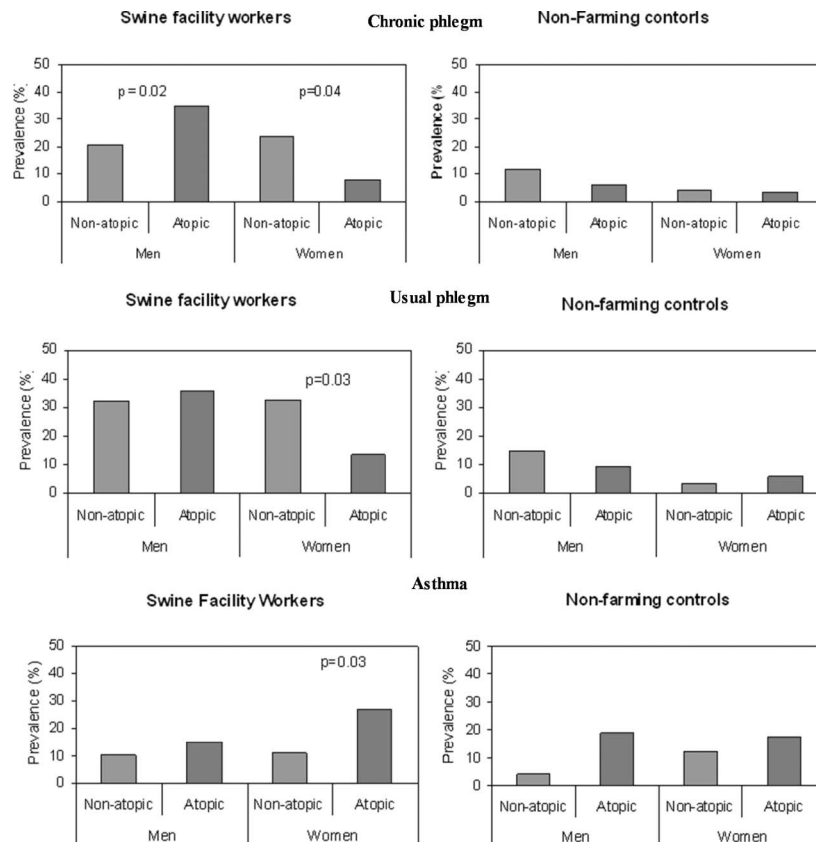


TABLE 2. Relationship Between Atopy and Symptoms for Males and Females Among Swine Workers and Nonfarming Controls*

	Chronic phlegm OR (95% CI)	Usual phlegm OR (95% CI)	Chronic cough OR (95% CI)	Usual cough OR (95% CI)	Asthma OR (95% CI)
Swine workers					
Atopy					
No	1.0	1.0	1.0	1.0	1.0
Yes					
Males	1.97 (1.05, 3.67)	1.27 (0.63, 2.03)	2.34 (1.17, 4.67)	1.99 (1.07, 3.70)	1.58 (0.69, 3.60)
Females	0.28 (0.08, 1.01)	0.30 (0.10, 0.87)	0.45 (0.17, 1.17)	0.66 (0.28, 1.58)	2.50 (0.91, 6.88)
Nonfarming controls					
Atopy					
No	1.0	1.0	1.0	1.0	1.0
Yes					
Males	0.69 (0.22, 2.17)	0.89 (0.33, 2.37)	2.17 (0.64, 7.37)	2.45 (0.90, 6.83)	4.78 (1.51, 15.11)
Females	0.81 (0.19, 3.41)	1.76 (0.48, 6.48)	1.53 (0.56, 4.23)	1.36 (0.59, 3.17)	1.49 (0.70, 3.19)

*Results from logistic regression after controlling for age, years worked and smoking for swine workers, and age and smoking for nonfarming controls.

OR, odds ratio; CI, confidence interval.

atopy was statistically associated with decreased symptoms related to cough and phlegm, but that atopy was associated with increased susceptibility to asthma among the female workers. Adjusting for use of asthma medications did not modify the results observed for male and female workers in Table 2. Atopic male nonfarming control subjects had an increased risk of asthma but this increased risk was not seen in atopic female control subjects (Table 1).

DISCUSSION

In swine workers, atopic females were less likely to have chronic phlegm and usual phlegm, chronic cough and usual cough in comparison to nonatopic females. Associations between atopy and chronic and usual cough were not observed in male workers nor were the associations statistically significant in females. However, asthma was more prevalent among atopic females in a pattern not seen in men. The prevalence of atopy was similar in male workers and male control subjects, and in female workers and female control subjects, and males had a higher prevalence of atopy compared to females, suggesting that selection of workers based on atopy was not likely a significant factor, and also that the swine barn environment

was likely not causal of atopy in male or female workers. The results also suggest that female swine workers with atopy have a reduced incidence of symptoms involving excessive sputum production (such as productive cough), but have an increased likelihood of being diagnosed with asthma by a doctor.

This study, in our view, adds to a growing body of information that appears to indicate that the respiratory system in female workers may respond differently to contaminants in the ambient environment than does the respiratory system of male workers. Although the female workers were present in the barns for a greater number of hours per day (8.2 ± 1.0 hours in females versus 7.7 ± 1.7 hours in males), this modest difference appears to be offset by the males working a greater number of days worked per week (5.6 ± 1.0 versus 4.9 ± 0.4) and more years total (6.5 ± 7.0 versus 4.1 ± 4.1) compared to female workers.

Information to date on the respiratory effects of swine barn exposures has been based primarily on the now passing phenomenon of the male farmer owner operator with intermittent exposure showing increased respiratory symptoms,⁷ reductions in expiratory flow rates,⁷ airways hyperresponsiveness,⁸ and excess longitudinal decline in expiratory flow rates⁹⁻¹¹ associated with exposures to dust, endotoxin,

hydrogen sulfide, and ammonia.^{16,17} The observations that we herein report, and those of our previous report,¹ are among the first to evaluate the relatively new phenomenon of the full-time employed swine worker, and within that development, the recent occurrence of the full time female swine worker.¹ In that context, our previous report on the full-time male and female swine workers demonstrated increased prevalence of symptoms suggestive of chronic bronchitis (~30%), but the symptoms appeared to be present more commonly in the female as compared to the male workers,¹ suggesting the possibility of a differential effect in the female workers compared to their male counterparts.

There is evidence that environmental exposures may result in excess respiratory symptoms in women as compared to men.^{1,18} In our previous studies of lung function in rural dwellers, women appeared to have increased evidence for airflow obstruction when compared to men, even though the women had less smoking exposure.¹² It has also been shown that women first-degree relatives of smokers had enhanced airways responsiveness as compared to men relatives.¹⁴ Women also appeared to have more variation in response to inhaled lipopolysaccharides than did men.¹⁹ There may be gender differences in the development of chronic obstructive pulmonary disease,¹³ and gender differences in respiratory outcomes in occupational exposures.¹⁵ The reasons for these apparent differences in the lungs of women versus men in response to environmental exposures are not clear. We have previously speculated that the smaller size of women's lungs might predispose the lungs of women to airway obstruction as a result of particulate exposures.¹² In the work of Kline and colleagues in which the female group was significantly more sensitive than the male group in the response to inhaled lipopolysaccharides, it was speculated that male-female differences in lipoproteins might affect the response to lipopolysaccharides.¹⁹ This being the case, it is possible that the inflammatory response of the lung in women is different than in men, leading to differences in the way in which the lungs of women might respond to inhaled particulate.

We showed in our analysis that the increased risk in female workers was independent of the

risk related to smoking. It is possible that female workers could be exposed to higher levels of dust and endotoxin as their job descriptions have female workers spending a greater proportion of their time in farrowing operations (54.8%) than do male workers (36.5%), and workers might have closer contact with pigs in the farrowing operations than in finishing operations. It has been shown that respirable dust fractions in swine barns are higher in farrowing barns than in finisher barns, but as in the current study, endotoxin concentrations were not measured in that study.³

We have previously shown that wearing a mask reduces short-term respiratory effects in naïve volunteers in the swine barn,²⁰ but in the study that we herein report, male and female workers reported similar use of protective masks. We have also previously reported on cases of newly developed asthma in male and female workers shortly after commencing employment in the swine industry and have made the observation that a common feature of the four female workers described was that virtually all of them had been naïve to swine barn exposures until the time of their commencement of employment,²¹ but this information was not available for the female workers in our study.

As with any cross-sectional study, there are certain limitations, including the biases that may be associated with this kind of study. Also, our study does not include measurements of the principal contaminants known to affect respiratory health outcomes such as dust, endotoxin, hydrogen sulfide, and ammonia. However, there is information suggesting that the new larger facilities in which the participants in this study worked have levels of contaminants similar to the older facilities in which most of the previous studies on male farm owner-operators took place.² As noted in our previous report on this population,¹ we do not have previous occupational histories.

We believe that this study demonstrates additional evidence that there may be gender differences in respiratory response associated with occupational exposures. These findings raise the issue that occupational health programs may need to be structured in such a manner as to

fully protect the health of both women and men workers. In addition, from the research perspective, there is a need for a cohort study to determine the longer term effects of swine barn exposure in male and female full-time workers in the new large scale swine production facilities.

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